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In a Biology laboratory for the non-science major, a series of programed booklets, 8mm cartridge films, and 35mm slides were used with standard laboratory equipment and materials. By the end of the second semester, 28 programed sequences with linear and branching strategies had been designed and tested. Students completed attitude questionnaires after each unit that helped decide sequential revisions for the spring, and lab quizzes that denied correlation between achievement and time spent in the laboratory. Programed laboratory units met their instructional objectives with the mean above 78% in all but one of the nine units tested and 86% of all student scores at the level of 70% or above. While 88% of fall students approved of this approach to laboratory instruction, units were subdivided and further coordinated with lectures for the spring. Among many conclusions were these: sequences reached pre-stated objectives for non-science majors; a laboratory station can serve at least 16-18 students during a 40-hour week; time for sequence completion varies, and new objectives may be added to such a course. Quiz and questionnaire results, selected student comments, and lists of terminal objectives are given. (TI)

research report

NUMBER 3

A PROGRAMED BIOLOGY LABORATORY FOR THE NON-SCIENCE MAJOR

INSTRUCTIONAL RESOURCES CENTER

STATE UNIVERSITY COLLEGE
FREDONIA, NEW YORK

NUMBER 3

A PROGRAMED BIOLOGY LABORATORY FOR THE NON-SCIENCE MAJOR

ROBERT M. DIAMOND

JUNE 1968

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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A PROGRAMED BIOLOGY LABORATORY

FOR THE NON-SCIENCE MAJOR

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BACKGROUND

In the spring of 1968 a decision was made at the State University College at Fredonia to explore an independent learning approach to the laboratory portion of the one semester Biology course for the non-science major. Earlier work by Postlethwait and others[1] at Purdue University had indicated that an approach of this type could be both instructionally effective and administratively efficient.

The Purdue experiment in Freshman Botany utilized a combination of media with written items and laboratory materials supporting the main instructional program which was contained in a series of audio tapes. It was first thought that these materials might have immediate application to the Fredonia program. Careful analysis soon indicated that the two courses were dissimilar in both objectives and student population and that use of the Purdue materials would not be practical.

It was, therefore, decided to design a programed laboratory sequence to meet the specific needs of the course. To support this project, funds were provided for the partial release time of faculty during the spring semester and for the employment of those who would write the programed materials over the summer. The laboratory sequence that evolved differs in many basic ways from the Purdue approach. This report describes, in detail, the development of this Biology laboratory for the non-science major.

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[1]S. N. Postlethwait, J. Noval and H. Murray, An Integrated Experience Approach to Learning with Emphasis on Independent Study, Burgess Publishing Co., 1964.

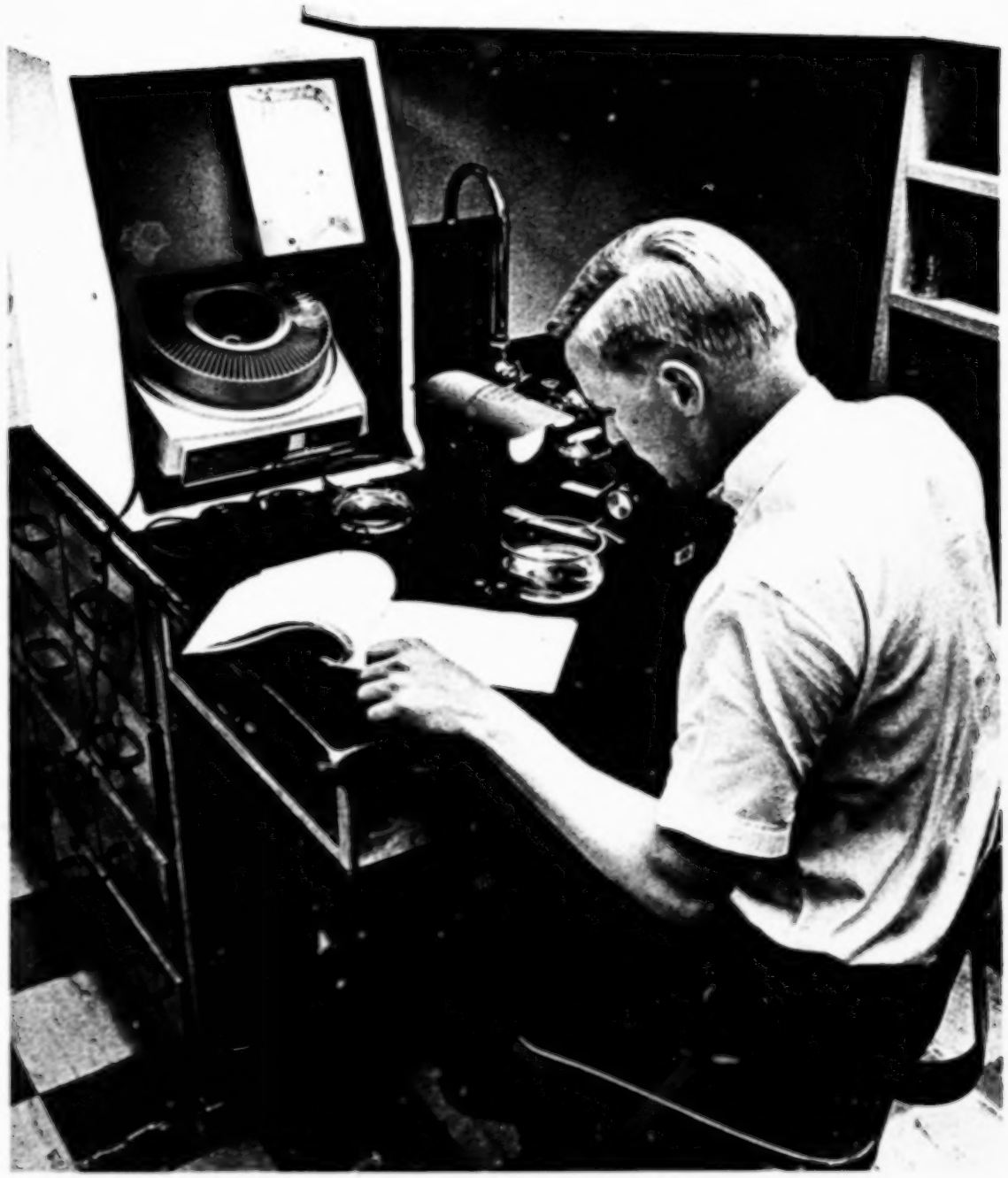
PROCEDURE

Once the relationship between the lectures, discussion group and laboratory was established, a primary step was the identification of objectives for the laboratory sequence. As a result of this analysis a specific series of terminal (behavioral) objectives were established for each laboratory period. Objectives for several units will be found in Appendix A. All evaluation instruments used in this project were based on these objectives. During the period covered by this report the course consisted of two, one hour lectures, a one hour discussion seminar led by graduate assistants, and the programed laboratory. Enrollment in Biology 111 was 145 for the fall and 124 during the spring semester.

After exploring the various techniques that were available, it was decided to combine a series of programed booklets with 8mm cartridge films, 35mm slides and standard laboratory equipment and materials. The audio approach was not selected as it was felt that a programed booklet could provide greater flexibility while substantially reducing the total cost of the individual carrel.

A standard laboratory of 24 student stations was redesigned for this experiment by the placing of carrel dividers on the existing laboratory tables. These carrels contained shelves, had access to water and a sink, and held a rear screen unit designed to hold either an 8mm cartridge film or slide projector. (See illustrations following page.) As a result of this modification, the number of student positions available in the laboratory was reduced to twelve. For this project, eight stations

In the Biology laboratory, a movable partition separated the standard laboratory table into two independent learning stations. Programed booklets were used in conjunction with standard laboratory equipment, 8mm cartridge films and 35mm slides. The slide and film materials were projected on a rear screen unit designed for the purpose.



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were used, with an additional one set up with the previous week's sequence for those students who had, for some reason, fallen behind.

An approximate cost of the individual carrels will be found in Table I. (This does not include standard laboratory equipment and materials or the programed booklets.)

TABLE I

COST PER STUDENT STATION

8mm cartridge film projector	$112.00
35mm slide projector	106.00
Carrel (materials & construction)	60.00
Instructional material	
8mm films (five--one produced locally)	71.00
35mm slides	22.00
TOTAL ADDITIONAL COST	$371.00

In another departure from the Purdue approach, individual carrels were, for the most part, self-contained, with students completing an entire sequence in a single carrel. Students would, however, be referred to a central table for some materials and reference exhibits. Many weeks consisted of more than one sequence that could, at the discretion of the student, be completed at one sitting or separately. The laboratory was open, generally, from 9:00 A.M. to 5:00 P.M. with students free to take as much or as little time as they wished. The laboratory was, at all times, under the supervision of a graduate student in Biology.

Thirteen programed laboratories were written during the spring and summer with the laboratory becoming operational in the fall of 1967. A specific writing sequence was followed for each unit. The steps were as follows:

1. Statement of objectives in behavioral terms.
2. Preparation of criteria test based on objectives.
3. Content outline prepared.
4. Related 8mm cartridge films previewed (if available).
5. Films or slides selected for use.
6. First draft of programed sequence written.
7. Sequence edited and checked for content accuracy.
8. Field test on three or four students.
9. Revision.
10. Field test in formal course (fall 1967).
11. Revision.
12. Formal evaluation (spring 1968).

Revisions were made as a result of the first major field test in the fall semester with formal evaluation beginning in the second semester of use. The course is a one semester course for students not majoring in science. By the end of the second semester, 28 individual programed sequences had been designed and field tested with all but three of these of subject orientation. The three exceptions were the course introduction and units covering the operation of the slide and 8mm cartridge film projectors that would be used. The branching and linear programing strategies were used with the individual programs containing from 30 to 100 pages. The specific format utilized in an individual sequence was dependent upon the nature of the

material being covered, with several units combining both approaches. Since student stations were designed to hold either a cartridge film projector or a slide projector, use of these two pieces of equipment were not combined. Cartoons were included to provide a change of pace for the student. A list of individual programed sequences and the media used will be found in Table II.

TABLE II

INDIVIDUAL PROGRAMED SEQUENCES & MEDIA USED

LAB NO.	SEQUENCE	MEDIA USED
	Introduction	
1A	Physical Properties of Protoplasm	
1B	Introduction to Chemical Indicators	
2A	Parts of the Microscope	
2B	Using the Microscope	
2C	Acceptable Laboratory Drawings	
S	The Carousel Slide Projector	
3A	Animal Cells and Tissues	11 Kodachrome Slides - Adipose, Nerve, Leaf Cx.
3B	Plant Cells and Tissues	
C	The 8mm Cartridge Film Projector	
4A	Squash Technique	8mm Film Loop - "Comparison of Chromosome Behaviour in Meiosis and Mitosis", Gateway.
4B	20 Minute Mitosis Review	"Cell Division"(EBF)
5A	Asexual Reproduction	14 Kodachrome Slides - Bacteria, Hydra, Moss, Algae, Yeast, Protozoans
5B	Sexual Reproduction	
6	Gametogenesis	5 Kodachrome Slides - Corpus Luteum, Ovary, Testes
7A	Heredity and Probability	
7B	Genetics	

TABLE II (continued)

LAB NO.	SEQUENCE	MEDIA USED
8	Embryology	6 Kodachrome Slides - Starfish
9	Development of the Coelom in the Animal Kingdom	16 Kodachrome Slides - Ascaris, Earthworm, Hydra, Planaria
10A	Major Groups of Algae	11 Kodachrome Slides - Many types of algae; Spirogyra, Oscillatoria, Cladophora, Diatoms, Desmids
10B	Growth Forms in Algae	
11A	Fungi	
11B	Bacteria	
12A	Life Cycle of a True Moss	8mm Film Loop, "Gamete Transfer in the Bryophytes", Modern Learning Aids.
13A	External Anatomy of the Leopard Frog (Rana Pipiens)	8mm Film Loops, "The Frog: External Anatomy", EBF.
13B	Internal Anatomy of the Leopard Frog (Rana Pipiens)	"The Frog: Internal Anatomy", Fredonia.
14 A	Ecology	

Evaluation: During the first (fall) semester, a questionnaire on general attitudes was given prior to and at the completion of the course. Each week a random group of students were given a brief questionnaire on pacing, content and general reaction to that week's laboratory. These weekly questionnaires proved to be extremely useful during the revision period.

The revised sequences, used during the spring semester, were evaluated by the use of the individual criteria tests based on the pre-stated behavioral objectives for each unit. These tests were, when possible, administered to several of the discussion sections selected on a random basis. In addition, a small group of students completed the weekly questionnaire.

Some major modifications were made between semesters with one unit, Ecology, replacing the frog sequence for evaluation purposes.

A space utilization survey was conducted during both semesters to determine optimum hours of operation and ideal scheduling patterns. A record of the time required to complete each laboratory was kept for each student with a Pearson correlation being performed to explore any possible relationship between performance and time spent in the laboratory.

The sequence (systems approach) used in the development of this laboratory effected major changes in both the scope and content of the laboratory from what had existed previously. As a result, no comparison between this laboratory and the one that it replaced was possible.

RESULTS

When scheduling permitted, a criteria test for each week's work was administered to several of the discussion groups during the following week. Groups were selected at random without any warning to the students. For week 3, quizzes were given on each of the two units within that sequence. Results will be found in Table III.

TABLE III

LABORATORY QUIZ RESULTS

	WEEK								
	1	2	3A	3B	4	5	7	8	9
n	48	66	18	45	43	18	55	84	37
SCORE (in percents)									
96-100	15	3	7	7	2	1	29	15	6
91-95	7	22	7	8	4	2	4	6	
86-90	8	30	3	6	5	3	1	8	14
81-85	8	7		5	3	4		5	2
76-80	2	3		5	8	4	3	17	6
71-75	3			4	5	2	1	12	4
66-70	2			2	5	1	3	6	1
63-65	1		1	1	1	1	1	1	
62 or below	1			2	11		13	14	4
Mean (%)	88.1	90.2	94.3	82.7	71.2	83.6	83.6	78.7	82.7

A Pearson Correlation comparing quiz results and time spent in the laboratory was performed. Results will be found in Table IV.

TABLE IV

A COMPARISON OF ACHIEVEMENT AND TIME SPENT IN THE LABORATORY

Week	
1	-.02
2	-.10
3	.33*
4	-.05
5	-.02
7	.20
8	-.12
9	-.45**

* Significant at the .05 level of confidence.

** Significant at the .01 level of confidence.

During both semesters a random selection of students were given a short questionnaire. Results will be found in Tables V through XVIII.

TABLE V

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: 1A Physical Properties of Protoplasm
1B Introduction to Chemical Indicators

WEEK NUMBER: (Fall) one (Spring) one

NUMBER OF STUDENTS: (Fall) 33 (Spring) 20

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	5	15	5	25
b. interesting	23	70	15	75
c. of some interest	5	15	0	0
d. of little interest	0	0	0	0
2. I feel that the material was paced:				
a. too fast	0	0	0	0
b. a little fast	1	3	0	0
c. just right	31	93	17	85
d. a little slow	1	3	3	15
e. too slow	0	0	0	0
3. I feel that I learned:				
a. a great deal	9	27	7	35
b. some	22	67	11	55
c. not very much	1	3	2	10
d. very little	1	3	0	0
4. I found the sequence to be:				
a. very clear	25	76	17	85
b. clear	8	24	3	15
c. slightly confusing	0	0	0	0
d. very confusing	0	0	0	0

Selected student comments:

As compared to other labs I have taken, it is much more rewarding. It's an individual learning experience rather than a dull classroom lab experience.

I found the entire program relatively easy and very understandable.

I think it's the most fascinating lab I've ever had. I'm not a science brain, but I found it was the first lab I ever did and understood what I was doing. The instructions are very specific.

Gives you a feeling of accomplishment. Very good.

The experiment with the potato cubes was a little confusing as to the reason of water in the cells and its osmosis. The experiment on the indicators was easy.

TABLE VI

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Parts of the Microscope; Using the Microscope; Acceptable Laboratory Drawings

WEEK NUMBER: (Fall) 2 (Spring) 2

NUMBER OF STUDENTS: (Fall) 22 (Spring) 25

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	7	32	1	4
b. interesting	15	69	21	84
c. of some interest	0	0	3	12
d. of little interest	0	0	0	0
2. I feel that the material was paced:				
a. too fast	0	0	0	0
b. a little fast	1	5	1	4
c. just right	16	75	19	76
d. a little slow	5	21	5	20
e. too slow	0	0	0	0
3. I feel that I learned:				
a. a great deal	8	36	10	40
b. some	13	59	13	52
c. not very much	1	5	0	0
d. very little	0	0	0	0
no answer	0	0	2	8
4. I found the sequence to be:				
a. very clear	13	59	18	72
b. clear	9	41	7	28
c. slightly confusing	0	0	0	0
d. very confusing	0	0	0	0

Selected student comments:

The entire lab was fairly easy and at a steady even pace.

I don't think anything should be changed. The pace of the work is just right to be easily done with understanding.

The instructions say the materials are to be found in front of me. Most of them weren't. If I have to locate them myself, please indicate this in the instructions.

TABLE VII

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Animal Cells and Tissues
Plant Cells and Tissues

WEEK NUMBER: (Fall) 3 (Spring) 3

NUMBER OF STUDENTS: (Fall) 25 (Spring) 16

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	4	16	2	13
b. interesting	16	64	10	62
c. of some interest	3	12	4	25
d. of little interest	1	4	0	0
no answer	1	4	0	0
2. I feel that the material was paced:				
a. too fast	2	8	1	6
b. a little fast	3	12	0	0
c. just right	15	60	13	81
d. a little slow	4	16	2	13
e. too slow	0	0	0	0
no answer	1	4	0	0
3. I feel that I learned:				
a. a great deal	10	40	6	38
b. some	12	48	9	56
c. not very much	1	4	0	0
d. very little	1	4	1	6
4. I found the sequence to be:				
a. very clear	14	56	10	62
b. clear	9	36	5	31
c. slightly confusing	1	4	1	6
d. very confusing	0	0	0	0
no answer	1	4	0	0

Selected student comments:

It was long, but it kept my interest.

No change except that maybe this lab should have been made into two labs--it was quite long.

No change, except in some instances it was difficult to recognize parts of the cell under the microscope.

TABLE VIII

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Squash Technique - 20 minute Mitosis

WEEK NUMBER: (Fall) 4 (Spring) 4

NUMBER OF STUDENTS: (Fall) 34 (Spring) 14

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	14	42	3	21
b. interesting	19	57	11	79
c. of some interest	1	3	0	0
d. of little interest	0	0	0	0
2. I feel that the material was paced:				
a. too fast	0	0	0	0
b. a little fast	2	6	2	14
c. just right	25	75	11	79
d. a little slow	7	21	1	7
e. too slow	0	0	0	0
3. I feel that I learned:				
a. a great deal	20	60	9	64
b. some	13	39	5	36
c. not very much	1	3	0	0
d. very little	0	0	0	0
4. I found the sequence to be:				
a. very clear	14	42	9	64
b. clear	17	51	4	29
c. slightly confusing	3	9	1	7
d. very confusing	0	0	0	0

Selected student comments:

Good lab this week -- have never seen mitosis before.

Film was interesting.

I enjoy doing the labs as I have a sense of accomplishment when they are finished.

All information we had previously received about mitosis was unclear, but this lab cleared the entire problem up.

It was difficult finding certain stages--couldn't find all of them.

TABLE IX

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Asexual Reproduction - Sexual Reproduction

WEEK NUMBER: (Fall) not included (Spring) 5

NUMBER OF STUDENTS: (Fall) none (Spring) 22

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting			4	18
b. interesting			15	68
c. of some interest			3	14
d. of little interest			0	0
2. I feel that the material was paced:				
a. too fast			0	0
b. a little fast			1	5
c. just right			17	77
d. a little slow			2	9
e. too slow			2	9
3. I feel that I learned:				
a. a great deal			9	41
b. some			12	54
c. not very much			1	5
d. very little			0	0
4. I found the sequence to be:				
a. very clear			18	81
b. clear			4	19
c. slightly confusing			0	0
d. very confusing			0	0

Selected student comments:

It was clear and easy enough. I think the directions are easy to follow and therefore you can learn the material.

I found that everything was explained clearly. I thought the slides helped you to understand.

The lab was very clear and constant repetition makes sure you understand it.

This was the best lab so far.

I feel that the idea of this lab situation is fine, but one can read at home, why is this lab necessary?

TABLE X

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Gametogenesis

WEEK NUMBER: (Fall) 5 (Spring) 6

NUMBER OF STUDENTS: (Fall) 25 (Spring) 22

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	10	40	3	16
b. interesting	15	60	14	74
c. of some interest	0	0	2	10
d. of little interest	0	0	0	0
2. I feel that the material was paced:				
a. too fast	0	0	0	0
b. a little fast	7	28	3	16
c. just right	18	72	12	63
d. a little slow	0	0	3	16
e. too slow	0	0	0	0
no answer	0	0	1	5
3. I feel that I learned:				
a. a great deal	11	44	10	53
b. some	14	56	8	42
c. not very much	0	0	0	0
d. very little	0	0	0	0
no answer	0	0	1	5
4. I found the sequence to be:				
a. very clear	10	40	8	42
b. clear	9	36	9	47
c. slightly confusing	6	24	2	11
d. very confusing	0	0	0	0

Selected student comments:

Please identify exactly the parts mentioned.

Booklet explains exactly what the student should do. If the student follows the directions, he will find the lab easy. If a student skips over pages and doesn't read everything, he'll get lost.

The microscope slides weren't clear to me. I think the slide projector should have been used instead.

TABLE XI

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Heredity and Probability -- Genetics

WEEK NUMBER: (Fall) 11 (Spring) 7

NUMBER OF STUDENTS: (Fall) 20 (Spring) 21

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	0	0	4	19
b. interesting	12	60	12	57
c. of some interest	4	20	4	19
d. of little interest	4	20	1	5
2. I feel that the material was paced:				
a. too fast				
b. a little fast	4	20	6	29
c. just right	15	75	14	67
d. a little slow	0	0	0	0
e. too slow	1	5	0	0
no answer	0	0	1	5
3. I feel that I learned:				
a. a great deal	4	20	8	38
b. some	11	55	12	57
c. not very much	1	5	1	5
d. very little	2	10	0	0
no answer	2	10	0	0
4. I found the sequence to be:				
a. very clear	8	40	2	10
b. clear	6	30	11	52
c. slightly confusing	6	30	7	34
d. very confusing	0	0	1	5

Selected student comments:

A few more problems should be done for us in the lab booklet. They should be somewhat like the problems we were asked to do ourselves.

At times it was a little vague but overall it was clear and easy to follow.

The material contained in this booklet was not as clear as the other booklets. The latter quarter of the book did not go into enough detail to solve the problems.

TABLE XII

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Embryology

WEEK NUMBER: (Fall) 6 (Spring) 8

NUMBER OF STUDENTS: (Fall) 23 (Spring) 24

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	2	9	3	13
b. interesting	19	83	17	71
c. of some interest	2	9	3	13
d. of little interest	0	0	1	4
2. I feel that the material was paced:				
a. too fast	0	0	0	0
b. a little fast	1	4	0	0
c. just right	20	87	21	88
d. a little slow	1	4	2	8
e. too slow	0	0	1	4
no answer	1	4	0	0
3. I feel that I learned:				
a. a great deal	8	35	12	50
b. some	15	65	9	37
c. not very much	0	0	1	4
d. very little	0	0	1	4
no answer	0	0	1	4
4. I found the sequence to be:				
a. very clear	14	61	16	67
b. clear	8	35	8	33
c. slightly confusing	1	4	0	0
d. very confusing	0	0	0	0

Selected student comments:

Good concise lab that got right to the point. It helped a great deal towards understanding the notes given in lecture on Embryology.

The biology lecture was not as easy to understand as the lab was. I feel that the lab should come before the lecture--it would make it much more clear.

It gave good follow-up to the lecture and clarified certain details.

Pleasant, short, easy to comprehend. More labs should be like this clear sequence of slides, coordinated with the book.

TABLE XIII

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Development of Coelom in the Animal Kingdom

WEEK NUMBER: (Fall) 7 (Spring) 9

NUMBER OF STUDENTS: (Fall) 23 (Spring) 17

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	1	4	1	6
b. interesting	14	61	11	65
c. of some interest	7	31	4	24
d. of little interest	1	4	1	6
2. I feel that the material was paced:				
a. too fast	1	4		
b. a little fast	5	22	6	35
c. just right	16	61	9	53
d. a little slow	1	4	1	6
e. too slow	0	0	1	6
3. I feel that I learned:				
a. a great deal	13	57	10	59
b. some	10	44	6	35
c. not very much	0	0	0	0
d. very little	0	0	1	6
4. I found the sequence to be:				
a. very clear	7	30	2	12
b. clear	9	39	7	41
c. slightly confusing	7	30	6	36
d. very confusing	0	0	2	12

Selected student comments:

I found it quite easy but interesting.

Some of the various parts of the animals being considered weren't pointed out clearly enough.

It's Mickey Mouse.

I found it difficult to locate the different parts mentioned in the booklet on the animal.

TABLE XIV

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: (A) Major Groups of Algae
(B) Growth Forms of Algae

WEEK NUMBER: (Fall) 8 (Spring) 10

NUMBER OF STUDENTS: (Fall) 28 (Spring) 22

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	2	7	2	9
b. interesting	10	36	13	59
c. of some interest	9	32	6	27
d. of little interest	4	14	1	5
no answer	3	11	0	0
2. I feel that the material was paced:				
a. too fast	10	36	0	0
b. a little fast	8	29	3	14
c. just right	4	14	16	73
d. a little slow	0	0	2	9
e. too slow	0	0	0	0
no answer	6	21	1	5
3. I feel that I learned:				
a. a great deal	6	21	10	46
b. some	6	21	10	46
c. not very much	6	21	1	5
d. very little	9	32	0	0
no answer	1	4	1	5
4. I found the sequence to be:				
a. very clear	1	4	10	46
b. clear	9	32	11	50
c. slightly confusing	7	26	1	5
d. very confusing	11	39	0	0

Selected student comments:

It was easy to obtain materials and specimens needed, and all help necessary to complete this lab.

Slides--good supplement to microscope work--in the cases you didn't see it well by yourself.

It was slightly confusing on the oscillatoria--the difference between the filament and the trichome.

TABLE XV

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Fungi -- Bacteria

WEEK NUMBER: (Fall) 9 (Spring) 11

NUMBER OF STUDENTS: (Fall) 16 (Spring) 20

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	0	0	3	15
b. interesting	8	50	7	35
c. of some interest	7	45	8	40
d. of little interest	1	5	1	5
no answer	0	0	1	5
2. I feel that the material was paced:				
a. too fast	0	0	1	5
b. a little fast	3	20	1	5
c. just right	12	75	17	85
d. a little slow	1	5	0	0
e. too slow	0	0	0	0
no answer	0	0	1	5
3. I feel that I learned:				
a. a great deal	4	25	2	10
b. some	10	65	14	70
c. not very much	1	5	2	10
d. very little	1	5	2	10
4. I found the sequence to be:				
a. very clear	7	45	7	35
b. clear	8	50	10	50
c. slightly confusing	1	5	2	10
d. very confusing	0	0	0	0
no answer	0	0	1	5

Selected student comments:

Too general--not exactly confusing, but I felt that this particular lab was not of any significant value--the different fungi were barely described--could have been done in a more specific way.

The entire lab was interesting.

I'd like to make my own slides.

TABLE XVI

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: (A) Life Cycle of a True Moss
(B) Life Cycle of a Fern

WEEK NUMBER: (Fall) 10 (Spring) 12

NUMBER OF STUDENTS: (Fall) 10 (Spring) 16

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	4	40	1	6
b. interesting	3	30	7	44
c. of some interest	2	20	6	38
d. of little interest	1	10	2	13
2. I feel that the material was paced:				
a. too fast	0	0	0	0
b. a little fast	0	0	1	6
c. just right	8	80	9	56
d. a little slow	1	10	4	25
e. too slow	1	10	0	0
no answer	0	0	2	13
3. I feel that I learned:				
a. a great deal	4	40	6	38
b. some	4	40	8	50
c. not very much	1	10	1	6
d. very little	1	10	1	6
4. I found the sequence to be:				
a. very clear	6	60	5	30
b. clear	3	30	6	38
c. slightly confusing	1	10	2	13
d. very confusing	0	0	3	19

Selected student comments:

I found this week's lab to be very interesting but a little slow in its repetition and questioning.

Diagrams were easily understood; but were of less interest than usual.

Try to use some demonstration materials instead of just reading the materials. It becomes boring.

I feel that this type of lab should be paced just like today's lab was.

TABLE XVII

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: Ecology

WEEK NUMBER: (Fall)_____ (Spring) 13

NUMBER OF STUDENTS: (Fall)_____ (Spring) 25

	Spring n	Spring %
1. I feel that this sequence was:		
a. extremely interesting	0	0
b. interesting	15	60
c. of some interest	6	24
d. of little interest	3	12
no answer	1	4
2. I feel that the material was paced:		
a. too fast	0	0
b. a little fast	3	12
c. just right	15	60
d. a little slow	3	12
e. too slow	1	4
no answer	3	12
3. I feel that I learned:		
a. a great deal	12	48
b. some	10	40
c. not very much	0	0
d. very little	3	12
4. I found the sequence to be:		
a. very clear	10	40
b. clear	11	44
c. slightly confusing	2	8
d. very confusing	1	4
no answer	1	4

Selected student comments:

I thought the material was presented very well. It was easy to understand and not very difficult to learn.

I thought the sequence was very good. It was easy to follow and not confusing, therefore, it kept your interest.

I didn't mind the hoola-hoop and found people's reactions very amusing, but I thought the material in the book was easy and totally ridiculous.

I did the exact same experiment in high school and it taught me nothing I didn't already know.

TABLE XVIII

QUESTIONNAIRE RESULTS

SEQUENCE TITLE: (A) External Anatomy of the Leopard Frog
(B) Internal Anatomy of the Leopard Frog

WEEK NUMBER: (Fall) 12 (Spring) _____

NUMBER OF STUDENTS: (Fall) 46 (Spring) _____

	Fall		Spring	
	n	%	n	%
1. I feel that this sequence was:				
a. extremely interesting	6	13		
b. interesting	30	65		
c. of some interest	6	13		
d. of little interest	2	4		
no answer	2	4		
2. I feel that the material was paced:				
a. too fast	2	4		
b. a little fast	3	7		
c. just right	29	63		
d. a little slow	5	11		
e. too slow	3	7		
no answer	4	9		
3. I feel that I learned:				
a. a great deal	15	33		
b. some	23	50		
c. not very much	4	9		
d. very little	2	4		
no answer	2	4		
4. I found the sequence to be:				
a. very clear	16	35		
b. clear	25	54		
c. slightly confusing	4	9		
d. very confusing	0	0		
no answer	1	2		

Selected student comments:

I enjoyed this more than any other lab we've ever had.

Diagrams a little hard to match up.

Reading the material and then seeing films on the same material immediately afterward was very helpful. However, the lab was too short--part B should have been included in this week's lab to learn the internal and external anatomy at the same time as the external anatomy wasn't hard or confusing at all.

A general student attitude questionnaire was administered at the beginning and end of the fall (first field test) semester. Results will be found in Table XIX.

TABLE XIX

GENERAL ATTITUDE QUESTIONNAIRE RESULTS

	1967 September		1968 January	
	n	%	n	%
1. Science courses taken in high school:				
Biology	137	97		
Physics	33	23		
Chemistry	109	77		
Earth Science	50	35		
General Science	115	81		
2. I have generally found science laboratory instruction (in any science) to be:				
extremely interesting	37	26		
of some interest	85	60		
of little interest	13	9		
dull	7	5		
3. I have generally found science laboratory instruction to be:				
extremely useful	29	20		
of some use	86	61		
of little use	24	17		
a waste of time	3	2		
4. I would rate my high school biology laboratory experience as:				
excellent	14	10		
good	69	49		
fair	36	25		
poor	13	9		
no answer	10	7		
5. I feel that biology is:				
a very interesting subject	74	52	76	55
of some interest	58	41	60	43
of little interest	1	1	2	2
of no interest	1	1	1	1
no answer	8	6		

TABLE XIX
(continued)

GENERAL ATTITUDE QUESTIONNAIRE RESULTS

	1967 September		1968 January	
	n	%	n	%
6. I feel that (all - not all) students should have some college biology.				
all	85	60	90	64
not all	43	30	48	35
no answer	14	10		
7. I feel that science in general is:				
a very important area of study for all students	42	30	38	27
of some importance for all students	94	68	94	68
a complete waste of time for some students	4	3	7	5
no answer	2	1		
8. I have found biology laboratory instruction to be:				
extremely useful	32	23	28	20
of some use	74	52	87	63
of little use	22	16	20	14
a waste of time	5	4	3	2
no answer	9	6		
9. I have found biology laboratory instruction to be:				
extremely interesting	53	37	41	29
of some interest	64	45	79	57
of little interest	11	8	12	9
dull	4	3	9	6
no answer	10	7		
10. In the biology laboratory:				
I was always busy	41	29	58	42
usually busy	73	51	62	45
busy at times	15	11	17	12
seldom busy	2	2	2	2
no answer	11	8		
11. I found the lecture portion of this course to be:				
extremely interesting			67	48
of some interest			66	47
of little interest			2	2
dull			2	2

TABLE XIX
(continued)

GENERAL ATTITUDE QUESTIONNAIRE RESULTS

	1967 September		1968 January	
	n	%	n	%
12. I found the lecture portion of this course to be:				
extremely useful			57	41
of some use			66	47
of little use			11	8
a waste of time			5	4
13. I found the recitation period to be:				
extremely interesting			10	7
of some interest			50	36
of little interest			44	32
dull			35	25
14. I found the recitation period to be:				
extremely useful			9	6
of some use			58	42
of little use			41	29
a waste of time			31	22
15. I (did - did not) like this approach to laboratory instruction.				
did			122	88
did not			17	12
16. I (did - did not) like the idea of going to laboratory at my own convenience.				
did			126	91
did not			13	9
17. I (did - did not) like the cartoons in many of the laboratory booklets.				
did			127	91
did not			12	9
18. As far as the cartoons go, I would:				
have some in all the booklets			56	40
leave the amount the same			70	50
eliminate them			13	9
19. I (would - would not) like to see more laboratory instruction of this type.				
would			123	88
would not			15	11

Selected student comments:

As long as a person can stay on some sort of schedule with himself and make it to lab each week on his own, he'll cover the required work. I enjoyed the bits of comic relief in the booklets--makes the learning more enjoyable and relaxed. However, I feel we need three lecture sessions each week--little was accomplished in the recitation period.

In the beginning, it was difficult to get into the lab, but after awhile everyone set up their own schedule and went at the same time every week so getting in became less difficult. The booklets were organized in such a way that it was easy to grasp the information.

I prefer this laboratory much, much more than the regular labs. The instruction booklets were clear enough so that the student was capable of independent work. According to individual capabilities, some students can work faster than others, and naturally following, some students have to work slower. These labs give the individual student as much or as little time as necessary. I would definitely like to see more lab classes like this one.

The best thing about this experimental lab set-up is that you can come to it and complete it at your own convenience. I was able to take as much time as I needed to absorb the material.

I think the laboratory portion of the course was much more interesting this way than just following a general lab book. I think it could have been better if the lab lecture and recitation coordinate more, or perhaps it should have more organization.

It was fairly interesting--and more enjoyable by being able to go at my own convenience and leave as soon as I was finished--I feel I got more out of doing the work independently.

For once in my life I went to a lab without dreading it. For a change, it was easy to understand and they had the decency to leave out all the professional jargon. I actually learned something, too!

I found them very cohesive and easy to follow. The directions were quite simple and the material was easy to understand. On some of the more intricate things of biology which are hard to see in the microscope, a film could have been much simpler and easier to understand.

It was far superior to any lab I have ever attended. Sometimes I found it genuinely pleasurable--and I am not of a scientific turn of mind. One suggestion: the timing could have been better. Some labs ran as long as 2-1/2 hours, while one took less than fifteen minutes.

Selected student comments (continued):

It is a very interesting way to run a laboratory. While the student is forced to do his own work, he is not penalized by the different learning speeds of his classmates. It is perhaps the most valuable part of Biology 111.

Lab was often quite interesting and easy to understand. I learned quite a lot in this laboratory. I also liked going at my own convenience.

The laboratories were usually very interesting, however, at times they were paced somewhat too slowly. The addition of slides and tapes seemed to help, especially during the labs on reproduction.

Doing the laboratories on my own; working at my own pace helped in better understanding the material.

I thought it was useful. The only thing that was annoying was having to wait if all the stations were being used.

It was undoubtedly the most interesting science lab I've experienced. I wish others would follow suit. Three hour labs of unclear work is too trying. Biology labs were clear, concise and funny.

Psychologically knowing that you won't be burdened by a two to three hour group lab is quite lifting. The information appeared to be a bit scant but they are designed to get across the basics which I think is great. I learned a great deal more from this lab than when I failed the course two years ago.

Was good being able to go at your own convenience and I liked the programed approach, but the labs were too easy.

I thought the laboratories were useful. They made it easier to understand what we were studying. Only one was a complete waste of time and that was the last one on Ecology.

Some labs could have been more interesting; for example, I just read in some of them. There should be more actual experimentation.

The books were fairly clear, cartoons made it more interesting. There should be more microscope work and fewer drawings (I can't draw) or else we should be able to copy the drawings out of the booklets. Trying to draw from slides I find very difficult.

The lab I felt was an ideal lab. Almost perfect. It would have been better perhaps if you could have introduced some method of note taking during the lab. That would be a help to those idiot students (me!) who took poor notes and thought that they would remember it. I enjoyed 90% of the labs.

I thought the lab was very interesting. The only minor problem was that it wasn't really geared to the book; always a lapse of time between the book and lab.

Selected student comments (continued)

I have found that programed learning is extremely interesting and useful. Instead of stumbling through the lab in a daze, the booklets assume that the student knows what he's doing by correcting mistakes and guiding him through. Also the student is able to progress at his own speed, and his actions are "reinforced" immediately (if correct). In conclusion, then, I have found this lab system very rewarding and interesting. I hope that other courses can be set up on this basis.

An analysis of the time required for students to complete the weekly sequences will be found in Table XX.

TABLE XX

TIME REQUIRED TO COMPLETE WEEKLY SEQUENCE
(Based on random selection of ten students)

Spring Semester

Week	Average (in minutes)	Range (in minutes)
1	86	65-102
2	69	45-90
3	135	105-185
4	80	55-110
5	42	30-50
6	79	45-120
7	93	60-140
8	37	25-55
9	62	25-120
10	75	50-105
11	46	30-90
12	48	20-75
13	37	25-50

Of the ten students used in this sample, five were both the slowest and fastest for different weeks of the semester. The two students who took the longest amount of time for most laboratories (four) also finished in the least amount of time in one other. Two additional students were the slowest for three weeks and the fastest for two.

During the spring semester, an hourly count was made of the number of stations occupied. Results will be found in Tables XXI and XXII.

TABLE XXI

SPACE UTILIZATION
(in percents)
EIGHT STATIONS AVAILABLE[1]

	Monday	Tuesday	Wednesday	Thursday	Friday
A.M. 9:00	78%	24%	71%	75%	68%
10:00	50	51	58	73	89
11:00	22	22	41	45	67
12:00	26	Closed	21	Closed	52
P.M. 1:00	75	78	74	63	57
2:00	88	70	76	67	89
3:00	50	62	56	59	47
4:00	24	38	32	38	48
Daily Average	52	49	54	60	65

[1]Weeks with ten stations available not included.

TABLE XXII

SPACE UTILIZATION BY SELECTED WEEKS
NUMBER OF STATIONS OCCUPIED

	Mon.	Tues.	Wed.	Thur.	Fri.
Stations	8 10 10	8 10 10	8 10 10	8 10 10	8 10 10
Week	3 4 7	3 4 7	3 4 7	3 4 7	3 4 7
9:00 A.M.	6 9 5	0 5 1	8 8 5	8 6 6	7 8 8
10:00	6 7 4	1 9 5	8 9 4	7 10 8	8 10 9
11:00	1 2 2	1 6 4	8 7 0	7 2 8	8 8 9
12:00	2 2 3	closed	5 1 0	closed	8 3 6
1:00 P.M.	5 7 5	8 8 4	8 9 6	7 9 7	8 3 7
2:00	8 10 6	8 8 6	7 9 10	7 10 9	8 4 8
3:00	7 8 3	8 6 8	7 7 6	7 7 8	8 4 2
4:00	3 6 1	8 6 10	6 1 4	6 3 9	8 1 2

DISCUSSION

While not equal in their instructional effectiveness, the programed laboratory units met their instructional objectives with the mean above 78% in all but one of the nine units tested and 86% of all student scores at the level of 70% or above. In several of the units, particularly the one on Genetics, there was a tendency for the students to be at one extreme or the other with twenty-four of the fifty-five students tested receiving 100% while thirteen others scored under 62%.

There was generally no correlation between the time spent in the laboratory and in instructional achievement, supporting

the hypothesis that in a well-programed unit, completion is the critical factor, not the amount of time involved. The unit on Animal and Plant Cells (week 3) did have a slightly positive correlation (at the .05 level of confidence) which may be due to the extreme length of that sequence. Week 9, Fungi and Bacteria, showed a significant negative correlation with no significance being found in the other six units tested. As will be noted later, the Fungi unit was one of the least popular sequences with the students.

While overwhelmingly in favor of this approach to laboratory instruction (88%), the fall semester students did make a series of suggestions that were incorporated into the revised materials used the second semester. Besides minor problems within individual booklets, there were three major changes between the two editions.

1. Several units were divided into smaller segments and scheduled during separate weeks.
2. There was a major increase in the use of 35mm slides. Students preferred 35mm slides over the standard microscope slide as it was possible on the projected slide to use pointers to highlight the area being discussed. It was found that the use of 35mm slides not only assured that students were seeing what was expected, but reduced substantially the cost per station and the amount of breakage. During the second semester, with the exception of the unit introducing the microscopes, only student-made microscope slides were used with

all others being projected on the rear screen unit.

3. Units were rescheduled to coordinate more closely with the lecture sequence.

The revisions were, for the most part, successful. Clarity was improved, pacing corrected, and for some units, major increases in both student interest and learning were achieved.

As a result of student reactions to the first implementation of the project in the fall, major revisions were made in two of the units; Heredity & Probability (Genetics) and Groups and Growth Forms of Algae. First, both units were rescheduled to fit more closely into the lecture pattern. Second, the instructional booklets were rewritten with major revisions in content and approach. As a result of these changes, the Genetics unit showed a major increase in interest with 38% of the students stating that they learned a great deal. The modifications in the Algae sequence increased the number of students stating that the unit was interesting or extremely interesting from 43% to 68%, that it was paced correctly from 14% to 73%, that it was very clear from 4% to 46%, with 46% as against 21% stating that they learned a great deal.

While general attitudes towards Biology did not appear to be affected by the course, the students found the laboratory useful (83%), of some interest (86%) and stated that they were usually busy (86%). It was interesting to note a substantial increase in the number of students who stated that they were always busy when compared to previous Biology

laboratories taken in high school.

Students were more favorable in their attitudes to the lecture and laboratory portions of the course than to the recitation periods with the lectures rating higher than the laboratory in both interest and usefulness. Over 20% of the students stated that the recitation period was a waste of time. The cause for this reaction needs further study. A large proportion of the negative comments (approximately 5%) were from students with extensive Biology background who were no longer specializing in this area. The course was, in effect, too easy and repetitious for this group and their enrollment in a science sequence designed for the non-science major must be questioned.

The students strongly supported (87.7%) the programed approach to laboratory instruction with over 90% liking the idea of going to the laboratory at their own convenience. 91.3% liked the use of cartoons with 40.2% suggesting that the use of this technique be increased. 123 (88.4%) of the students stated that they would like to see more laboratory instruction of this type.

The length of time it took a student to complete a week's assignment varied greatly from week to week and from student to student. The longest sequence was week #3 on Cells and Tissues with students averaging two hours and fifteen minutes. Three weeks had averages of between thirty-five and forty-five minutes. It should not, however, be concluded that laboratory objectives were reduced for this project. By careful organization and by eliminating extra-

neous materials it appears that the programed sequences reduce substantially the amount of time that most students require to meet pre-stated objectives.[1] The efficiency of this approach, therefore, makes it possible to add additional objectives to the laboratory.

The variance in times that different students took to complete any given assignment was extensive, with some students taking twice as long to complete a given assignment. In some weeks the difference between the faster and slower students was in excess of one hour.

While some students did tend to be in the upper or lower quartiles on the time needed to complete a unit, there was, in effect, little or no consistency from one week to another. Attitude, related experience and a variety of other factors appear to affect the performance of a student on any given day.

Over the semester the number of students using the laboratory at any particular time or day varied extensively from week to week with no specific pattern of use developing. While students did tend, as the semester progressed, to come to the laboratory earlier in the week, Thursday and Friday remained the days of higher utilization. Quizzes in other courses, campus activities, the length of the week's assignment, and outside commitments appeared to affect the pattern of use. Students did appear to adjust their own schedule

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[1] A brief experiment in a programed Geology Laboratory unit at Fredonia indicated that the time required to achieve pre-stated objectives may be reduced from 40% to 50% by the use of programed materials.

to those times when they would have a better chance of finding a station available. The long lines of students waiting to get into the laboratory disappeared after the first few weeks of both semesters.

Average utilization of the stations was approximately 56% with each station serving approximately fifteen students during the forty hour week the laboratory was open. It can be anticipated that each station could serve approximately eighteen students during a forty hour week without extensive scheduling problems as long as the weekly assignments remain in their present average length. There appears to be no limitation as to the number of stations that could be established in a single room.

The graduate assistants assigned to the laboratory reported a major decrease in the amount of help requested by students between the two semesters. While certain weeks still required a trained person in Biology to be available, the majority of the units were completely self-contained with general supervision appearing to be the only requirement.

CONCLUSIONS

1. The programed Biology Laboratory sequences used in the project are effective in reaching their pre-stated instructional objectives for non-science majors.
2. Students are positive toward the programed approach and the ability to come to the laboratory at their own convenience.

3. A single station can serve a minimum of from sixteen to eighteen students during a forty hour week when used with the present instructional sequence. There appears to be no limit in the number of stations that can be located in a given room with the maximum number being dependent solely on the size of the room.
4. A standard laboratory station can be modified to utilize these materials at a cost of less than $400 for new equipment, instructional materials and carrel materials.
5. There is no correlation between achievement and time spent in the laboratory.
6. No pattern of use can be established from this project, with daily use--while slightly higher on Thursdays and Fridays--remaining generally constant.
7. The time required for students to complete a given sequence varied substantially with little consistency as to which students would finish sooner from one week to the next.
8. The efficiency of this approach makes it possible to add new objectives to the laboratory sequence.
9. When general supervision is required, the use of highly trained graduate students is unnecessary.
10. Students with extensive Biology backgrounds should not be registered in this course designed for the non-science major.
11. Students approved the use of cartoons to change pace within sequences.

12. The programed approach to laboratory instruction should be continued in this Biology course for the non-science major, with this approach being explored in other areas.

APPENDIX A

Terminal Objectives

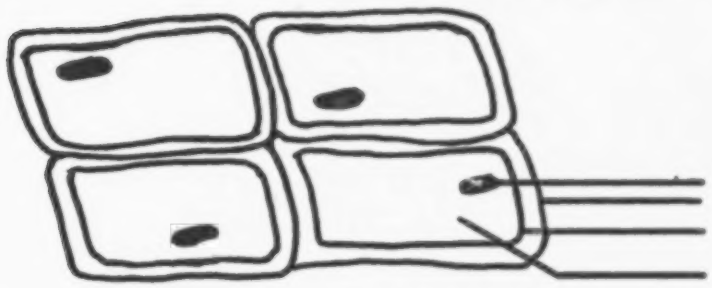
PLANT CELLS AND TISSUES

Booklet 3-B

Terminal Objectives

1. The student will be able to list the following four parts which are common to all plant cells:
   - cytoplasm
   - cell membrane
   - cell wall
   - nucleus

2. When shown the following drawing of several cells from the onion epidermis, the student will be able to label the following parts:
   - cell wall
   - cell membrane
   - cytoplasm
   - nucleus



3. The student will be able to correctly complete the following questions dealing with the cross section of a leaf. The correct answers are provided in the blanks.

   a. The entire leaf is surrounded by an epidermis which is made up of <u>cubodial</u> shaped cells.

   b. The epidermis is a protective layer. It reduces loss of <u>water</u> from the leaf.

   c. The stomates provide for the exchange of <u>gases</u> into and out of the leaf.

   d. The size of the stomates is regulated by the <u>guard cells</u>, which are located on each side of the stomate.

   e. The thin, nearly transparent, waxy layer which covers the epidermis is the <u>cuticle</u>.

   f. All of the cells between the upper and lower epidermal layers of the leaf are known collectively as the <u>mesophyll</u>.

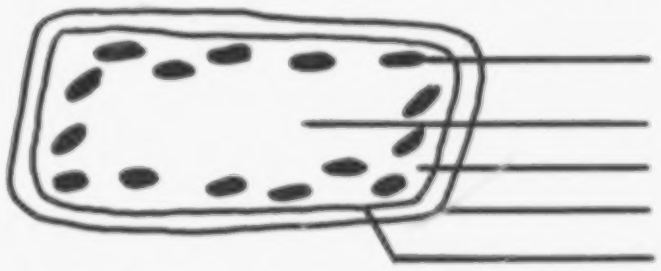
g. The cells referred to in question "f" are divided into two parts, the palisade layer and the spongy layer.

h. Of the two layers referred to in question "g", most of the photosynthesis occurs in the palisade layer.

i. The veins of the leaf consist mainly of two types of cells, the phloem and the xylem.

4. When shown the following diagram of an Elodea cell, the student will be able to label the following parts:

chloroplasts
cytoplasm
cell wall
cell membrane
vacuole



5. The student will be able to write the name of the process which each of the statements below describes. The correct answers are in parenthesis after the statements.

a. The cytoplasm moves around the cell. (cyclosis)

b. The cell contents shrink as water moves out of the cell. (plasmolysis)

PHYSICAL PROPERTIES OF PROTOPLASM

Booklet 1-A

Terminal Objectives

1. The student will be able to define, in writing, the following terms: Diffusion
   Osmosis
   Turgor

   The definitions should include:

   Diffusion: The net movement of molecules from an area of higher concentration toward an area of lower concentration.

   Osmosis: The net movement of water molecules through a semipermeable membrane from an area of higher concentration toward an area of lower concentration.

   Turgor: The condition in which plant cells are made rigid due to the water inside them.

2. When asked the following four questions, the student will be able to write a short answer for each of them. The expected answer follows each question.

   a. Question: Why does diffusion occur faster in hot water than it does in cold water?

      Answer: Diffusion is a molecular movement. Since hotter molecules move faster than do colder molecules, diffusion occurs faster in hot water.

   b. Question: When making a chromatogram, what must be the relationship between the liquid in the flask and the substance on the filter paper?

      Answer: The substance on the filter paper must be soluble in the liquid in the flask.

   c. Question: If you made two chromatograms with two different brands of the same color ink, how do you suppose the two chromatograms would compare? Why?

      Answer: They would probably be different, as the two brands of ink would most likely have different chemical compositions. You could not get identical chromatograms unless the chemical compositions were the same.

d. Question: A potato cube is placed in a dish of salt water. In which direction is the net movement of water molecules? Why?

Answer: The net movement will be out of the potato cells. In osmosis, the net movement of water is from an area of higher concentration toward an area of lower concentration. The concentration of water in the potato cells is greater than the concentration of water in the dish, thus the net movement of water is out of the potato.